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METALLURGY RESEARCH PROGRAM

RECOVERING GOLD FROM STRIPPING WASTE AND ORE BY PERCOLATION CYANIDE LEACHING

Heap leaching of low grade gold ores
– The complete story on this much published subject.

RECOVERING GOLD FROM STRIPPING WASTE AND ORE BY PERCOLATION CYANIDE LEACHING

by

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ABSTRACT

Simple and low-cost heap and vat percolation cyanide leaching methods were applied on a laboratory scale for recovering gold from submarginal mine strip material and from ores representative of deposits with limited reserves not justifying construction of a conventional cyanide treatment plant. Gold-bearing material, as coarse as 4 inches in size and assaying from 0.06 to 0.6 troy ounce per ton, was leached successfully with dilute cyanide-lime solutions. From 66 to 95 percent of the gold in the samples was dissolved and recovered in activated carbon. The amenable ores and materials invariably contained micron-size gold distributed throughout a porous, relatively cyanicide-free gangue.

INTRODUCTION

Gold-bearing rock can be effectively processed by heap or vat cyanide leaching techniques, provided the rock is competent, porous, and relatively free of cyanicides, and that the gold occurs as fine-sized clean particles. In heap leaching, run-of-mine or crushed rock is piled on an impervious base. The dilute cyanide-lime solution is distributed over the surface of the heap, collected, and recycled for weeks or months, depending on the depth and permeability of the heap and the size and permeability of the rock. In vat leaching, finely crushed or deslimed ground ore is carefully bedded in vats to assure permeability. Leaching is done by repeated upward or downward flooding with cyanide solution and draining the vat, or by intermittent downward percolation of cyanide solution. Several days to a week or more of leaching may be required. In either system, the low-strength pregnant solution may be treated continuously or intermittently with activated carbon to recover the gold.

In this research, conducted by the Bureau of Mines as part of a program to develop new domestic sources of gold, heap leaching practice was simulated by percolating cyanide solution through a loosely packed column of coarse ore with free draining of solution and by sprinkling solution on a heap of ore placed on a flat, slightly inclined impervious base. Vat leaching practice

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was simulated using a column of ore but employing downward flood leaching conditions. Activated carbon was used to remove gold from pregnant leach solutions continuously, except in comparative tests wherein solutions were recycled without gold removal.

TREATMENT OF LOW-GRADE STRIP WASTE

With the cooperation of a Nevada producing mine, several samples of low-grade mine strip waste were obtained for testing. Mineralogically the strip waste is composed of fine-grained, silicified limestone cut by numerous fractures filled with streaks of limonite and veinlets of calcite. The test lots obtained assayed 0.02 to 0.08 ounce of gold per ton. The gold occurs as fine particles, mostly minus 1 micron in size, accessible to cyanide leach solutions along fracture planes and through permeable rock.

We made column leaching tests on four stripping waste samples to simulate freely draining heap or vat percolation. The solution was slowly distributed on the surface of the ore and allowed to drain downward through the column. Pregnant gold solution was continuously stripped of its gold content by passing it through a bed of activated carbon before adjusting the cyanide and lime strength and returning the solution to the leaching cycle. Minus 1-inch ore in a loosely packed, 2-foot-high column was leached 6 to 7 days with solution containing 0.1 percent sodium cyanide and 0.01 percent calcium oxide. The results are given in table 1.

TABLE 1. - Column leaching of strip waste

Sample	Gold assay, oz/ton		Gold recovery, pct	Leaching time, hours	Reagent consumption, lb/ton	
	Head	Tail			NaCN	CaO
1	0.068	0.015	86	144	0.4	0.5
2	.022	.002	91	144	.5	.3
3	.047	.007	85	144	.4	.5
4	.085	.023	73	160	.7	3.5

The test results in table 1 show that from 73 to 91 percent of the gold was recovered. Reagent consumption was 0.4 to 0.7 pound of NaCN and 0.3 to 3.5 pounds of CaO per ton of ore treated.

To confirm the results of the column leach test, we leached a heap prepared from a composite sample of the four lots of strip waste. Strip waste crushed to 1-1/4 inches and mixed with about 4 pounds of calcium hydroxide per ton was placed in a heap 35 inches in diameter and 14 inches deep, with an 8-inch-diameter flat top. The heap, containing 340 pounds of ore, was percolated with a solution of 0.1 percent NaCN and 0.01 percent CaO at the rate of 100 ml per minute, sprinkled from a rotating distributor pipe. This is equivalent to 6 gallons per square foot per day, or 1 ton of solution per ton of ore per day. During the 510-hour leaching period, gold was continuously stripped from pregnant solution with activated carbon. Gold recovery was 76 percent from the 0.08-ounce composite head, leaving a tailing assaying 0.02 ounce.

TREATMENT OF GOLD ORES

Because heap and vat leaching require relatively low capital investment, we investigated the applicability of these methods to a variety of ores from deposits with insufficient reserves to warrant building a conventional cyanide plant. The results of testing a suite of samples from a small gold deposit in north-central Nevada are typical.

The four test samples contained 0.09 to 0.6 ounce of gold per ton of ore. The gold occurred as finely divided clean particles smaller than 1 micron, widely distributed throughout breccia composed of altered flow rock fragments cemented with silica and iron oxides. The ore is highly fractured and porous.

Samples of minus 1/2- to minus 4-inch ore, as received, were packed loosely in glass columns, 2 to 6 inches in diameter and 2 to 4 feet tall. Cyanide solution containing 0.1 percent NaCN and CaO was slowly added to the columns and allowed to trickle freely downward through the ore. The pregnant solution was continuously stripped of gold by passage through a small column of activated carbon, and the stripped solution was then adjusted to original cyanide and lime concentration before recycle to the columns. Table 2 gives the results of these tests.

TABLE 2. - Simulated heap leaching, gold ores

Sample	Ore size, inches	Gold assay, oz/ton		Gold recovery, pct	Leaching time, hours	Reagent consumption, lb/ton	
		Head	Tail			NaCN	CaO
1	1/2	0.63	0.03	95	48	0.7	2.7
2	4	.25	.04	83	1,000	1.0	4.9
3	2	.20	.03	84	864	1.0	4.3
4	2	.09	.03	67	552	1.0	5.6

As indicated in table 2, the different grades and sizes of ore are amenable to heap leaching with dilute cyanide solutions. Gold recoveries in laboratory tests were 67, 83, and 95 percent for the lowest, medium, and highest grade ores, respectively. The required leach time ranged from 48 hours for minus 1/2-inch ore to 1,000 hours for the minus 4-inch ore. Reagent consumptions ranged from 2/3 to 1 pound of NaCN and 2.7 to 5.6 pounds of CaO per ton of ore.

RESEARCH ON PROCESS VARIABLES

Our current research is focused on identifying and defining the key process variables that influence the rate and completeness of the dissolution of gold. These studies are incomplete; hence, we can offer only a few generalizations about the results obtained to date on the several suites of ores and strip wastes we have tested.

By comparable testing, we have established that effective leaching with minimum consumption of cyanide and lime is attained by controlling the pH near

10.5 and maintaining the cyanide concentration near 0.1 percent. Stronger cyanide solution and lower pH both lead to higher cyanide consumption but do speed gold dissolution.

Cyanide solution flow rate has little influence on gold leach rate. Comparable extractions in the same time were obtained with solution flow rate ranging between 20 and 775 gallons per square foot of area per 24 hours. Similarly we have successfully leached columns of ore from 2 to 12 feet high with no notable difference in the rate or completeness of extraction. Analysis of the effluent solution revealed that passage of the leach solution, through up to 12 feet of ore, does not significantly deplete the dissolved oxygen content.

Parallel tests established that use of activated carbon to strip gold from solution before the solution is recycled to columns or heaps of ore enables faster, but not necessarily more complete, gold dissolution. In the laboratory, activated carbon proved superior to zinc dust for recovering the gold from the lower tenor pregnant solution obtained by column and heap leaching of low-grade ores and strip wastes.

We have completed only empirical tests on the relationship of ore size and grade to leach rate and gold extraction. In the ores and strip waste tested, the percent of gold extracted is related to the grade, and the leach rate is apparently governed by the size and the solution permeability of the material being leached.

Notably, even after prolonged leaching of material containing 0.06 to 0.6 ounce of gold per ton, the residue still contained 0.002 to 0.03 ounce of gold per ton. Table 3 gives a typical screen analysis of the residue from leaching minus 4-inch ores assaying 0.2 and 0.09 ounce of gold per ton for 860 hours and 550 hours, respectively.

TABLE 3. - Screen analysis of typical leach residue

Size	Ore A (860-hr leach)		Ore B (550-hr leach)	
	Weight-percent	Au, oz/ton	Weight-percent	Au, oz/ton
Plus 1 inch............	35.0	0.05	42.4	0.05
Plus 10 mesh...........	41.3	.02	41.4	.02
Minus 10 mesh..........	23.7	.02	16.2	.01
Total and average...	100.0	.03	100.0	.03
Ore....................	-	.20	-	.09

FIELD TEST

The success achieved in laboratory heap leaching of mine strip waste from a Nevada gold producer encouraged the company to initiate larger scale field testing using conditions similar to those employed in the laboratory. About 500 tons of as-mined strip waste (minus 3 feet in size) was piled on a specially prepared sloping pad lined with impervious plastic. Leach solutions containing 0.1 percent NaCN and 0.09 percent CaO and maintained at pH 10 to 11

were sprinkled over the 4-foot-high heap at a rate of 30 gallons per square foot per day. Pregnant solution was collected in several sumps and pumped through small columns of activated carbon to remove dissolved gold. The lime and cyanide contents of the stripped solution were adjusted to original strength, and the solution was then recycled.

After 35 days of leaching, about 53 percent of the gold had been recovered from the heap of strip waste containing a calculated 0.075 ounce of gold per ton. Cyanide consumption was about 1.1 pounds of NaCN per ton of waste leached. Gold was still being extracted at a measurable rate when the test was terminated. Encouraged by the results of the first large-scale field test, the company is continuing its test program and is currently experimentally leaching two additional test heaps of strip waste to better define the process and improve the results.

SUMMARY

Laboratory tests show that cyanide leaching at coarse size of oxidized permeable ores and stripping wastes containing fine gold recovered 67 to 95 percent of the gold. About 1 week to 6 weeks of leaching was required. Reagent requirements were modest. In an initial field test on coarser stripping waste than used in laboratory work, gold dissolution was slower and lower than obtained in the laboratory. About 53 percent of the gold was extracted from material at a maximum size of 2 to 3 feet. The field test work is being continued.

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